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Morphological plasticity of Ilex theezans Mart. ex Reissek (Aquifoliaceae) in two restinga vegetation of Santa Catarina coastal plain

Plasticidade morfológica de Ilex theezans Mart. ex Reissek (Aquifoliaceae) em duas formações de restinga da planície costeira de Santa Catarina

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ABSTRACT

The *restinga*, an environment of the rain Forest, is an ecosystem by the seacoast composed of diverse plant communities commonly found in sandy and undeveloped soils. This study aims to investigate possible intraspecific differences in *Ilex theezans* species, whose distribution in *restinga* includes two heterogeneous formations, shrub-tree *restinga* and transition forest. The study focused on a *restinga* remnant area located in *Acaraí State Park*, in the city of São Francisco do Sul (SC, Brazil). In each environment, five adult individuals were selected and had wood samples collected from their stems at breast height and 25 leaves of the third and fourth nodes of the outer canopy branches sampled. Chemical and physical soil variables were analyzed for each formation. The results show that there are significant differences between the leaf and the stem functional attributes and soil data analyzed, but as the PPI (Phenotypic Plasticity Index), the species *Ilex theezans* in the studied formations present low plastic potential.
Keywords: Functional ecology; morpho-anatomy; phenotypic variation; population ecology; rain forest.

RESUMO

Restinga, ambiente litorâneo sobdomínio da mata atlântica, é um ecossistema costeiro composto por um conjunto diversificado de comunidades vegetais comuns em solos arenosos e pouco desenvolvidos. O presente estudo objetiva verificar possíveis diferenças intraespecíficas na espécie *Ilex theezans*, cuja distribuição na restinga abrange duas formações heterogêneas, restinga arbustivo-arbórea e floresta de transição. A área de estudo compreende um remanescente de restinga localizado no Parque Estadual Acaraí, no município de São Francisco do Sul (SC, Brasil). Em cada ambiente foi selecionada uma população composta por cinco indivíduos adultos; destes foram coletadas amostras de madeira do caule à altura do peito e 25 folhas dispostas no terceiro e quarto nós de ramos da copa externa. Analisaram-se variáveis químicas e físicas do solo para cada formação. Os resultados mostram que existem significativas diferenças nas médias entre os atributos funcionais foliares e caulinares e os dados de solo examinados, porém quanto ao Índice de Plasticidade Fenotípica (IPF) a espécie *Ilex theezans*, nas formações de estudo, apresenta baixo potencial plástico.
Palavras-chave: Ecologia funcional; ecologia de populações; mata atlântica; morfoanatomia; variação fenotípica.

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INTRODUCTION

The *Restinga* (sandbank) is a geologically recent ecosystem whose colonization occurred by species from other ecosystems or biomes such as the *Cerrado*, the *Caatinga* and even the Rain Forest, but with functional variations due to different conditions of its original environment (KLEIN *et al.*, 2007). According to Lacerda *et al.* (1993), in Brazil the vegetation of sandbanks occupies approximately 79% of the coastline, covering Holocene sandy deposits among dunes, ridges, spurs, plains generally spodosolic and formed by aeolian, lagoon, river, marine deposition or a combination of these (IBGE, 2012). The vegetation of sandbanks presents different communities distributed over a soil gradient, which have the herbaceous, shrub, shrub-tree and forest physiognomy, with growing diversity from post-beach towards the mainland region (MELO JÚNIOR & BOEGER, 2015).

Although considered a permanent preservation area, the sandbank is constantly threatened by human activities, with emphasis on real estate speculation and sand extraction (ASSIS *et al.*, 2004), which results, beyond species richness reduction, in loss of functional diversity of flora species.

Environmental factors can promote changes in the functional and structural characteristics of organisms exposed to them, in order to ensure their growth, development, survival and reproduction (GRIME & MACKEY, 2002). This alteration capacity of physiological, morpho-anatomical, ecophysiological and phenological attributes that an organism owns to response to changing environmental conditions is known as phenotypic plasticity (SCHLICHTING, 1986; VALLADARES *et al.*, 2006).

As an ecological consequence of these functional adjustments aggregated to the plastic potential of species, plants have the possibility to experience different habitats, explore richest niches in resources and expand their geographic distribution possibilities (SULTAN, 2000; BRADSHAW, 2006). Thus, the wide variation of the nutritional composition and water availability of sandbank soil is a precursor in the plants of structural adjustments, since the soil is an important conditioner and limiting factor for the development of species, especially when it refers to the expression of leaf structural adjustments and conducting water (MELO JÚNIOR, 2015; MELO JÚNIOR & BOEGER, 2016).

Plants present in the sandbank, growing close to the sea, are subject to more stringent and stressful environmental conditions than plants growing in tighter formations within the continent (SCARANO *et al.*, 2001). In sandbank environments, plants are subject to permanent salt deposit from sea, high temperature and luminosity and heavy wind, along with sand, that can cause mechanical damage to plants (ULIAN *et al.*, 2012). In addition, sandbank plants are, in sandy soils, poor in nutrients and permeable to water (SOUZA & CAPELLARI JÚNIOR, 2004).

Thus, this study aims to evaluate the plastic potential of *Ilex theezans* Mart. ex. Reissek. (Aquifoliaceae), in different sandbank formations of a coastal plain in northeast Santa Catarina. The choice of this species stems from its high abundance and importance value in the community structure of the sandbank in study. It has been hypothesized that the environmental conditions of the sandbank promote structural adjustments in the selected species. The predictions of this hypothesis are: a) increased investment in functional attributes associated with stem growth from higher nutritional supply from soil, especially the content of organic matter and CTC; b) the differentiated water condition among the sandbank soils promotes trade off in the wood.

MATERIAL AND METHODS

STUDY ÁREA

The study area comprises a remnant sandbank located in Acaraí State Park, São Francisco do Sul, SC, Brazil, under the 26º17'S and 48º33'W coordinates (figure 1). It is a conservation area with an approximate area of 6,667 hectares in the coastal plain and is considered the most important continuous remnant of coastal ecosystems of Santa Catarina (FATMA, 2006).

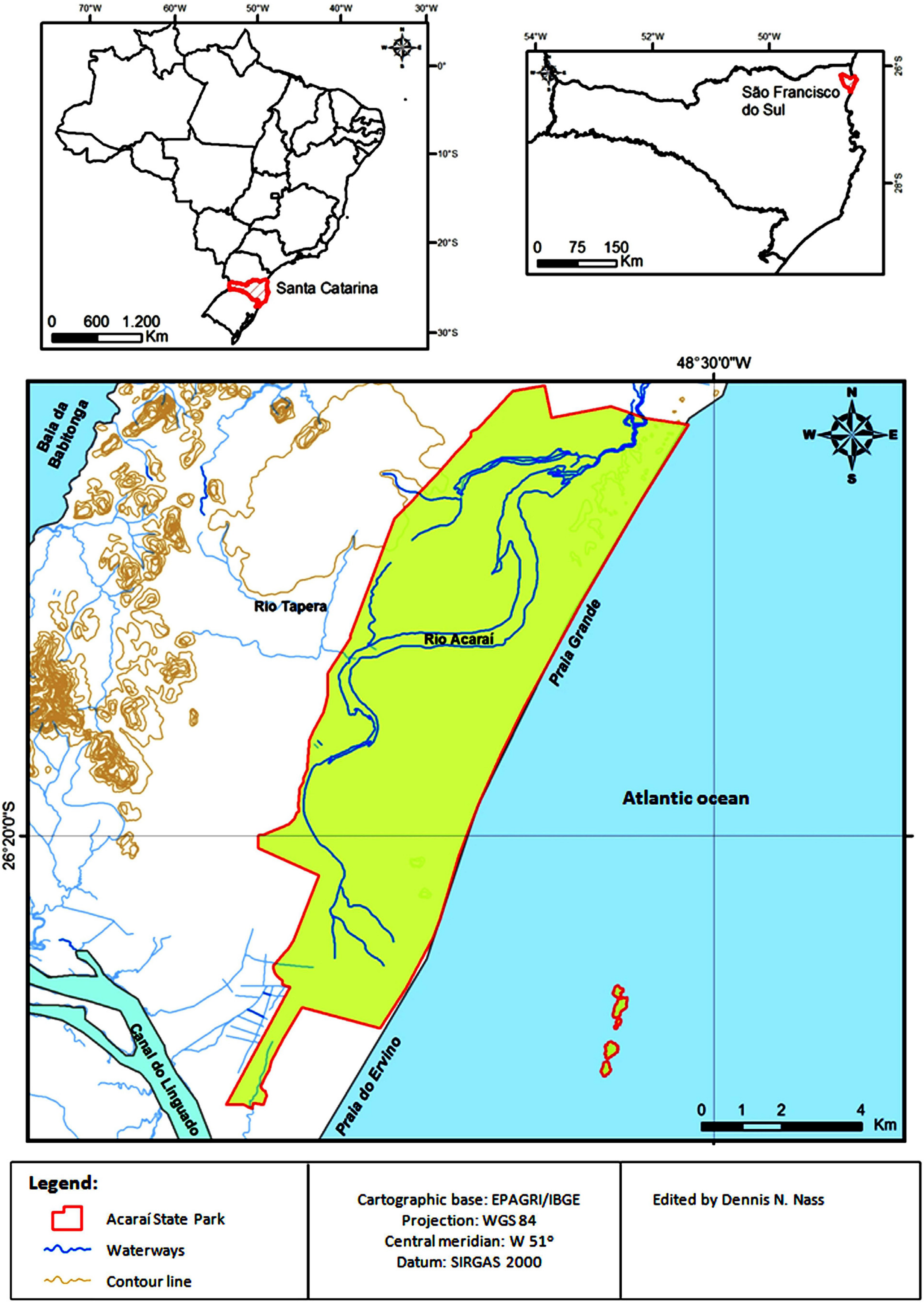

Figure 1 – Localization of the study area, Acarai State Park, São Francisco do Sul / SC. Source: Melo Júnior (2015).

The climate, influenced by maritime humidity, is mesothermal with no defined dry season and with hot summers (Cfa, according to Köppen). It is considered humid with average annual temperature of 20.3 °C and average rainfall of 1,874 mm / year, with rainfall well distributed throughout the year, in addition to presenting common occurrence of south wind that brings to the atmosphere ocean humidity, making the winter humid (KNIE, 2002; STCP, 2009).

The vegetation of the park (figure 2) belongs to the domain of *restinga* and is compartmentalized in formations with characteristic floristic and structural composition, which are distributed from the post-beach area to the Capivaru pond margins. The following formations stand out: herbaceous *restinga* (Rh), shrubby *restinga* (R), shrub-tree *restinga* (Raa) and the transition forest (Ft) (MELO JÚNIOR & BOEGER, 2015), This study was realized in both last cited formations and in areas defined as RAPELD portions of the module of biodiversity research program on rain forest (PPBioMA), installed on Acaraí State Park.

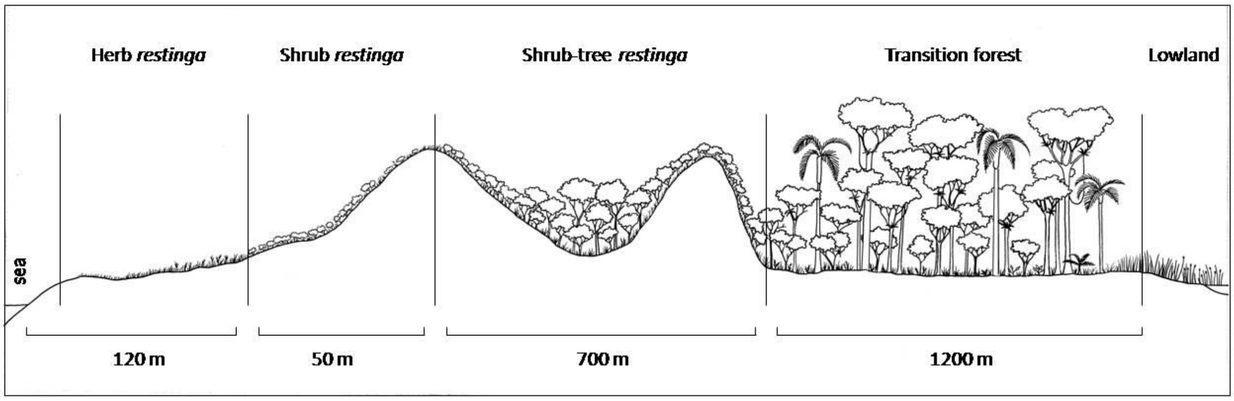

Figure 2 – Profile of formations of *restinga* at the Acarai State Park, São Francisco do Sul / SC. Source: Melo Júnior & Boeger (2015).

STUDIED SPECIES

Aquifoliaceae is represented by shrubs or trees with wide geographic distribution, consisting of a single genus, *Ilex* L., with about 400 species, of which 60 occur in Brazil, mainly in south and southeast (GROPPO, 2015).

Ilex species are well represented in the sandbank environments in the northeast part of Santa Catarina and few come to occupy a prominent position in the organization of the community of shrub-tree sandbank formation (MELO JÚNIOR & BOEGER, 2015). Thus, the selection of the species resulted from the abundance of individuals in the sandbank, allowing a systematic and valuable sampling. Another criterion is associated with the fact that *Ilex theezans* is considered a species with high importance value in the sandbank in question (MELO JÚNIOR & BOEGER, 2015).

Two populations of *Ilex theezans* Mart. ex Reissek (Aquifoliaceae) were selected in two sandbank formations for data collection, totaling a sample group of ten individuals. The following were considered in this study the formations of shrub-tree *restinga* (Raa) and transition forest (Ft), the latter being an ecotone between the sandbank and the lowland rain forest.

COLLECTION AND PROCESSING OF PLANT MATERIAL

In the two formations of sandbank there were chosen, randomly, five individuals of *I. theezans* in adulthood, *i.e*, individuals who have reached reproductive age. From each individual there were collected 25 fully expanded leaves, arranged in the 3rd and 4th nodes from the branch apex. After the leaves herborizing, it was taken biometrics of the following functional leaf attributes: leaf area (cm^2) in a desktop scanner coupled to the Sigma Scan Pro software (Version 5.0, SPSS Inc., Chicago, IL, USA), leaf thickness (mm), width (mm) and length (mm) with the aid of a digital caliper, dry mass (g) in an analytical balance and leaf specific area (cm^2.g-1) using the formula AEF = a / MS, where a = leaf area and MS = dry mass (WITKOWSKI & LAMONT, 1991).

Timber was collected, from the same individuals of each population, in the form of wedges at breast height (1.3 m ground) in isolated individuals or from entire disk from tillers individuals. Wood samples were made for subsequent histological preparation. The material was softened by cooking in water and 30% glycerine (FERREIRINHA, 1958). After cooking, histological cuts were made in transversal, longitudinal tangential and longitudinal radial sections with the aid of microtome slide. Histological slides were produced based on the guidelines of Johansen (1940). Sections were cleared in sodium hypochlorite (NaClO), washed in distilled water, stained with safrablau and dehydrated in ascending ethanol series (KRAUS & ARDUIN, 1997). The assembly was performed with synthetic resin of the type stained varnish (VASCONCELOS *et al.*, 2006).

Permanent slides with dissociated material were produced by dipping wood samples in Franklin solution, stored in an oven at 60 °C (KRAUS & ARDUIN, 1997). The following functional attributes for the stem were considered: the maximum height of the individual sample (m), the trunk diameter at breast height (cm), the tangential vessel diameter (uM), the frequency of vessels (in / mm^2) and the vessel element length (um.)

From the above biometric data, there were calculated the conductivity index (CI) = r□ / F (radius in the fourth power divided by the average frequency of vessels) (ZIMMERMANN, 1983), vulnerability index (IV) = D / F (vessel average tangential diameter divided by the average frequency of vessels) and mesomorph index (IM) = IR x C (vulnerability index multiplied by the average length of the vessel elements) (CARLQUIST, 1977; 2001).

ENVIRONMENTAL VARIABLES

For the analysis of environmental variables, a soil sampling was performed of each formation, according to the methodology of Embrapa (2013). The collection was carried out in five holes up to 10 cm deep, the samples being later homogenized to obtain a compound sample *per* formation. The following parameters were evaluated: organic matter (OM), hydrogen potential (pH), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), aluminum (Al) and hydrogen (H), bases sum (SB), capacity of cation exchange (CEC), base saturation (V%) and salinity (Na). Chemical soil analyzes was conducted by the Agronomic Institute of Campinas (IAC). In addition, the litter thickness and the gravimetric humidity were measured (EMBRAPA, 2013).

DATA ANALYSIS

For all quantitative attributes, the Phenotypic Plasticity Index (IPF) the were calculated. This method of phenotypic plasticity is based on the ratio of the difference between the maximum average and minimum average by the maximum average of a certain biometric variable (VALLADARES *et al.*, 2005).

Means and standard error were calculated for all analyzed leaf and stem functional attributes. The comparison between populations of *I. theezans* was performed using the Student t test in R environment (CRAWLEY, 2007). Pearson correlation tests were conducted to detect possible interactions between the functional biological attributes and the measured environmental variables (LEGENDRE *et al.*, 2011).

RESULTS AND DISCUSSION

In the soil analysis, the nutritional and fertility values differ between the formations. The values are considerably increasing toward the forest environment (table 1). The amounts of organic matter (OM), litter thickness (Ser) and gravimetric humidity (GM) were higher in the transition forest as well as the values of phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) cations.

The cation exchange capacity (CEC) was consequently higher in the transition forest (Ft). For the shrub-tree *restinga* (Raa), there were recorded hydrogenionic potential (pH), base saturation (V) and salinity (Na) values higher than those of the transition forest, which makes it a less fertile soil, more saline and alkaline when compared to the forest soil.

The high content of organic matter obtained in the transition forest provides greater fertility of the soil, which is proportional to the greater thickness of dead biomass deposited on the ground. Soil fertility can structurally influence the vegetation of sandbank (PEREIRA, 1990). The high organic matter content enable the reservation of reserves of phosphorus, calcium, magnesium and potassium nutrients, improves water holding capacity and influence pH (ZECH *et al.*, 1997). The organic matter content also promotes the increased cation exchange capacity (CEC), facilitating the exchange of essential cations to plant growth (Ca, Mg and K) by H + ions and may be the cause of reducing the pH in the surface layers of the soil which showed higher organic matter content, and hence greater retention capacity of H + ions (SANTOS & Camargo, 1999).

Table 1 – Analysis of soil fertility at the schrub-tree restinga formations (Raa) and transition forest (Ft) of Acarai State Park, São Francisco do Sul, Santa Catarina. Legend: organic matter (MO), hydrogen potential (pH), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), aluminum (Al), hydrogen (H), sum of bases (SB), cations exchange capacity (CTC), base saturation (V%), salinity, litter (Ser) and gravimetric humidity (UG). Values are mean and standard deviation (in brackets).

Environmental variables	Formation	
	Raa	**Ft**
MO (g/dm^3)	14,7 (± 3,8)	82,7 (± 9,1)
pH	3,5 (± 1,9)	3,1 (± 1,7)
P (mg/dm^3)	1,0 (± 1,0)	25,7 (± 5,1)
K ($mmolc/dm^3$)	1,3 (± 1,1)	2,3 (± 1,5)
Ca ($mmolc/dm^3$)	5,7 (± 2,4)	7,7 (± 2,7)
Mg ($mmolc/dm^3$)	1,0(± 1,0)	2,0(±1,4)
H + Al ($mmolc/dm^3$)	21,7 (± 4,6)	291,7 (± 17,1)
SB ($mmolc/dm^3$)	8,8(± 2,9)	13,8 (± 3,7)
CTC ($mmolc/dm^3$)	30,5 (± 5,5)	305,5 (± 17,5)
V (%)	29,0(± 5,4)	4,3 (± 2,07)
Salinity ($mmolc/dm^3$)	0,8 (± 0,9)	1,9 (± 1,4)
Litter (cm)	3,7 (± 1,9)	7,9 (± 2,81)
Gravimetric humidity (%)	14,1(± 3,7)	76,2 (± 8,7)

The low index of V% presented in transition forest means that there are small amounts of cations, such as Ca, Mg and K, saturating the negative charges of the colloids, the majority of them being neutralized by H + and Al3 +, which contributes to the acidity of soil that may even contain an aluminum toxic level to the plants (RONQUIM, 2010). In transition forest, H + and Al3 + values are much higher when compared to those obtained in shrub-tree *restinga*.

Soil fertility can interfere with sandbank vegetation structure (PEREIRA, 1990) and plays a key role in maintaining coastal ecosystems, as it holds the reserves of nutrients, improves water retention capacity, influence the pH and raises cation exchange capacity (CEC), preventing the leaching of cations (ZECH *et al.*, 1997). The average data of height and diameter (table 2) show increased investment in growth in individuals of *I. theezans* present in the transition forest. The fertility conditions of the transition forest enable and make more favorable the growth of the species, because of the amounts of organic matter and macronutrients P, Ca, Mg and K. The individuals present in the formation of shrub-tree sandbank, as they do not develop in a soil with favorable characteristics to growth investment, become smaller in their air architecture.

As well as environmental variables, leaf functional attributes showed significant differences between the studied formations (table 2). Mean values for leaf area, dry matter, leaf length and width were higher in transition forest. The leaf thickness and leaf specific area showed higher mean values in the formation shrub-tree *restinga*. These figures show that *I. theezans* has larger leaves in transition forest when compared to leaves in shrubby-arboreal *restinga*. This suggests that the plants are more shaded and have more accumulated biomass in the forest formation. The lower leaf area, observed in the population of the *restinga* shrubby-arboreal, is a strategy to prevent the loss of water through transpiration under conditions of high temperatures and in bright sunlight or due to low soil fertility (JAMES & BELL, 2001; BOEGER & WISNIEWSKI, 2003), these characteristics being more obvious in the sandbank formation in question. The assumption of the increase in biomass production, resulting in increased leaf area, depending on soil fertility (organic matter content and CTC) is supported by the high correlation value found here ($r = 0.74$, $n = 250$, $p < 0.0001$).

The leaf specific area expresses the ratio of leaf area by dry weight of the leaf. It is considered an important factor from a physiological point of view by describing the allocation of biomass leaf area per unit, reflecting the trade-off between rapid production of biomass and efficient conservation of nutrients (POORTER, 1994). The leaf specific area and leaf dry weight are important for the study of plant ecology, since they are associated with many aspects of plant growth and survival, being characteristic of resource use strategies (GARNIER *et al*., 2001; SHIPLEY & VU, 2002). Shade plants, such as those in transition forest, invest relatively higher proportion of photo assimilates in increased leaf area, to maximize capture of the available light. Generally, they exhibit thin sheets and have higher leaf specific area (LAMBERS *et al.*, 1998). Species with high values of leaf specific area exhibit high productivity and rapid growth capacity (REICH *et al.*, 1999; LI *et al.*, 2005), which explains the larger forest individuals, both in height and in diameter stem, compared to those of the shrubby-arboreal *restinga* (table 2).

Table 2 – Mean and standard deviation of leaf and stem functional attributes analyzed in populations of *Ilex theezans* in the formations of shrub-tree *restinga* (Raa) and transition forest (Ft) at Acarai State Park, São Francisco do Sul, Santa Catarina. Legend: different letters in the same row indicate statistical significance at 0,05 level.

Functional attributes	**Formation**	
	Raa	**Ft**
Leaf area (cm^2)	15,23 (± 4,81) ^{b}	28,17 (± 6,97) $^{a'}$
Leaf thickness (mm)	0,23 (± 0,05) ^{a}	0,21 (± 0,13) ^{b}
Leaf width (mm)	33,47 (± 5,33) ^{b}	45,53 (± 6,36) ^{a}
Leaf length (mm)	64,87 (± 12,76) ^{b}	88,73 (±11,85) ^{a}
Leaf dry mass (g)	0,27 (± 0,08) ^{b}	0,50 (± 0,16) ^{a}
Leaf specific area ($cm^2.g^{-1}$)	55,97 (± 11,12) ^{a}	58,43 (± 14,23) ^{a}
Plant height (m)	3,6 (± 0,9) ^{a}	6,1 (± 1,24) ^{b}
Stem diameter (cm)	21,3 (± 3,2) ^{a}	28,2 (± 9,09) ^{b}
Vessel element tangential diameter (μm)	57,06 (± 14,54) ^{a}	33,85 (± 8,36) ^{b}
Vessel element frequency (n/mm^2)	21,19 (± 5,19) ^{b}	27,59 (± 7,46) ^{a}
Vessel element length (μm)	1.014,94 (± 176,02) ^{b}	1.555,77 (± 422,31) ^{a}

Although there was no statistical difference for the AEF attribute, the lowest absolute value observed in individuals of shrubby-arboreal *restinga* may represent a major investment in mechanical tissues, given the greater plant exposure to luminous radiation since its top occupies the upper *stratum* in this formation. In forest environments (formation with more AEF) due to the heterogeneous distribution of light, it is expected that plants maximize light capture at the lowest cost in terms of investment and maintenance of tissues (GIVNISH, 1987). For this reason, the architecture of leaves in these environments is considered, in terms of selective pressure, a favorable element to the light interception (VALLADARES *et al*., 2002).

If compared the foliar data with the soil nutritional data, in places of low availability of resources, such as the shrub- tree *restinga*, what prevails is the conservative strategy, where the plant invests in slow growth, tissue protection and high investment in dry matter and presents low concentration of nutrients and low photosynthetic rate (LEMOS *et al*., 2011). It is noteworthy that the population of the formation transition forest presented a higher dry mass mean by having significantly larger leaves than that of the sandbank, which make them to be heavier.

Environmental changes reflect in structural changes in the wood, especially the size of the cellular elements, such as diameter, length and frequency of vessels (BAAS *et al.*, 1983). Regarding the vessel elements, the specimens present in the transition forest formation have a greater length of vessel elements and a higher frequency of vessels. In the formation of shrub-tree *restinga*, it can be seen that the tangential diameter of the vessel element is higher as compared to that obtained in forest environment (table 3). Regarding the functional and ecological characteristics of the xylem, Carlquist (1977) established mesomorphy and vulnerability indexes. Species of mesomorphic index greater than 200 are considered mesomorphs, according to Carlquist index (1977; 2001). *I. theezans* individuals analyzed presented mesomorphy index with values above this limit in the two formations of the sandbank of this study and *I. theezans* is considered a mesomorphic species.

Higher values of the vulnerability index indicate greater propensity to cavitation and hence the interruption of the water flow (CARLQUIST, 1977), which can be observed the formation of shrub-tree *restinga.* Since individuals of shrub-tree *restinga* showed higher tangential vessel diameter, the vulnerability index found in this population was higher than that obtained in the transition forest individuals (table 3). Therefore, the hydraulic conductivity in individuals of forest formation is considered safer and less susceptible to embolism or cavitation.

Higher conductivity indexes demonstrate greater efficiency in the transport of water (CARLQUIST, 2001). In this study, the formation of shrub-tree *restinga* showed higher conductivity, possibly due to increased vessel diameter.

According to Baas *et al.* (1983), larger vessels are more efficient but less safe due to the increased risk of blistering, which corroborates the values obtained for the Vulnerability Index (table 3). These figures show that the plants of the formation Raa are more vulnerable to embolism precisely because they have a more tangential vessel diameter in an environment where water scarcity is higher. On the other hand, such plants have increased transport efficiency evidenced by higher conductivity index (table 3), which is directly proportional to the greatest tangential vessel diameter. The proportionality between the tangential vessel diameter and water availability in the *restinga* soil proved to be positively correlated ($r = 0.50$, $n = 300$, $p < 0.0001$).

Table 3 – Indexes of vulnerability, mesomorphy and hydraulic conductivity of secondary xylem of *Ilex theezans* in shrub-tree *restinga* (Raa) and transition forest (Ft) at Acarai State Park, São Francisco do Sul, Santa Catarina.

Formation	Condutivity index	Vulnerability index	Mesomorphy index
Raa	5146,09	2,69	2733,01
Ft	489,51	1,22	1908,76

According to Castro *et al*. (2009), in environmental stress conditions, the plant invests in larger amounts of smaller diameter vessels to diminish the risk of embolism, as in this way vessels have greater adhesion of water on their walls, preventing the formation of air bubbles inside the vessel. This can be observed in the transition forest formation. The phenotypic plasticity index obtained for the leaf attributes (area and leaf dry mass) and timber (tangential vessel diameter) of *I. theezans* can be considered median (table 4). According to Valladares *et al.* (2005), variables with IPF higher than 0.6 are considered very plastic and those, whose IPF is close to 0, no plastic. Thus*, Ilex theezans* shows moderately plastic for certain morphological and anatomical attributes, which enhances the allocation of resources offered the sandbank environment. The other leaf and stem traits analyzed show low down plastic potential (table 4).

Table 4 – Phenotypic plasticity index (IPF) of the leaf and stem functional attributes of *Ilex theezans* at the two formations of shrub-tree *restinga* (Raa) and transition forest (Ft) at Acarai State Park, São Francisco do Sul, Santa Catarina.

Attributes	IPF
Leaf area (cm^2)	0,45
Leaf thickness (mm)	0,08
Leaf width (mm)	0,26
Leaf dry mass (g)	0,47
Leaf specific area (cm^2/g^{-1})	0,04
Leaf length (mm)	0,26
Vessel tangential diameter (µm)	0,40
Vessel frequency (mm^2)	0,23
Vessel element length (µm)	0,34
Average IPF	0,28

Although the studied populations of *Ilex theezans* were statistically different for all morphoanatomic attributes analyzed, it is believed that the low-moderate plastic potential observed may be related to spatial microscale distribution of populations of this species in remnant *restinga* studied. This idea supports the results obtained for other woody species studied in the same sandbank formations at Acaraí State Park (BÄCHTOLD & MELO JÚNIOR, 2015; SILVA & MELO JÚNIOR, 2016). It is also possible that other functional attributes to be more plastic compared to those dealt with here, making studies in plasticity an important Contribution to the definition of functional attributes in plants under the biodiversity studies of rain forest associated to PPBioMA.

CONCLUSION

In the shrub-tree *restinga*, characterized as a low fertility and water availability environment, there is a greater increase in tangential vessel diameter in an attempt to increase efficiency in water transport in an environment with strong drainable soil. In the forest environment, where there is greater availability of nutrients coming from the decomposition of organic matter, and more abundant water resources, the species invests in growth and photosynthetic production, which was evidenced by the height and stem diameter of the sample individuals, and longer vessels and in greater numbers per unit area, favoring them also a water efficiency compensated by the absence of tangential diameter larger vessels. Overall, the IPF values obtained show the low phenotypic plasticity of evaluated attributes for the species *I. theezans,* distributed in a spatial microscale at the *restinga* formations in this study.

REFERENCES

Assis, André Moreira de; Oberdan José Pereira & Luciana Dias Thomaz. Fitossociologia de uma floresta de restinga no Parque Estadual Paulo César Vinha, Setiba, município de Guarapari. Revista Brasileira de Botânica. 2004; 27:349-361.

Baas; Peter; Elizabeth Werker & Avraham Fahn. Some ecological trends in vessel characters. IAWA Bulletin. 1983; 4:141-159.

Bächtold, Barbra Aline & João Carlos Ferreira de Melo Júnior. Plasticidade morfológica de *Calophyllum brasiliense* Camb. (Calophyllaceae) em duas formações de restinga no sul do Brasil. Acta Biológica Catarinense. 2015; 2(2):21-32.

Boeger, Maria Regina Torres & Celina Wisniewski. Comparação da morfologia foliar de espécies arbóreas de três estádios sucessionais distintos de floresta ombrófila densa (floresta atlântica) no Sul do Brasil. Revista Brasileira de Botânica. 2003; 26(1):61-72.

Bradshaw, Anthony David. Unravelling significance of phenotipic plasrticity in plants. Advances in Genetics. 2006; 94(6):115-155.

Carlquist, Sherwin. Comparative wood anatomy: systematic, ecological, and evolutionary aspects of dicotyledon wood. 2 ed. New York: Springer; 2001. 448 p.

Carlquist, Sherwin. Ecological factors in wood evolution: a floristic approach. American Journal of Botany. 1977; 64(7):887-896.

Castro, Evaristo Manuel de; Fabricio José Pereira & Renato Paiva. Histologia vegetal: estrutura e função de órgãos vegetativos. Lavras: UFLA; 2009. 234 p.

Crawley, Michael James. The R book. Chichester: J. Wiley; 2007. 950 p.

Empresa Brasileira de Pesquisa Agropecuária – Embrapa. Sistema brasileiro de classificação de solos. 3 ed. Brasília; 2013.

Ferreirinha, Manuel P. Elementos de anatomia de madeiras folhosas portuguesas. Lisboa: Ministério do Ultramar; 1958. 89 p. (Memórias da Junta de Investigação do Ultramar).

Fundação do Meio Ambiente – Fatma. Plano de manejo do Parque Estadual do Acaraí. 2006.

Garnier, Eric; G. Laurent; A. Bellmann; S. Debain; P. Berthelier; B. Ducout; C. Roumet & M. L. Navas. Consistency of species ranking based on functional leaf traits. New Phytologist. 2001; 152:69-83.

Givnish, Thomas Joseph. Comparative studies of leaf form: assessing the relative roles of selective pressures and phylogenetic constraints. New Phytologist. 1987; 106:131-160.

Grime, John Philip & J. M. L. Mackey. The role of plasticity in resource capture by plants. Evolutionary Ecology. 2002; 16:299-307.

Groppo, Milton. Aquifoliaceae. In: Lista de espécies da flora do Brasil. Jardim Botânico do Rio de Janeiro. Disponível em: http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB4910. Acesso em: out. 2015.

Instituto Brasileiro de Geografia e Estatística – IBGE. Manual técnico da vegetação brasileira. 2. ed. São Paulo; 2012.

James, Shelley A. & David T. Bell. Leaf morphological and anatomical characteristics of heteroblastic *Eucalyptus globosus* ssp. *globosus* (Myrtaceae). Australian Journal of Botany. 2001; 49:259-269.

Johansen, Donald Alexander. Plant microtechnique. New York: McGrawHill; 1940. 523 p.

Klein, Alecsandro Schardosim; Vanilde Citadini-Zanette & Robson dos Santos. Florística e estrutura secundária de restinga herbácea no município de Ararangua, Santa Catarina. Biotemas. 2007; 20:15-26.

Knie, Joachin L. W. Atlas ambiental da região de Joinville: complexo hídrico da Baía da Babitonga. Florianópolis: Fatma/GTZ; 2002.

Kraus, Jane Elizabeth & Marcos Arduin. Manual básico de métodos em morfologia vegetal. Seropédica: Edur; 1997. 197 p.

Lacerda, Luiz Drude; Dorothy Sue Dunn Araújo & Norma Crud Maciel. Dry coastal ecosystems of the tropical Brazilian coast. In: Eddy Van der Maarel (ed.). Dry coastal-ecosystems: Africa, Asia, Oceania. Amsterdam: Elsevier; 1993. p. 477-493.

Lambers, Hans; F. Stuart Chapim III & Thijs L. Pons Plant physiological ecology. New York: Springer; 1998. 540 p.

Legendre, Pierre; Daniel Borcard & François Gillet. Numerical Ecology with R. Springer; 2011.

Lemos, Paula; Sheina Koffler; Marcos Samuel Macedo & Solimary Garcia. Folhas caras ou baratas? Estratégias de aquisição e uso de recursos de uma hemiepífita. Universidade de São Paulo; 2011. Disponível em: http://ecologia.ib.usp.br/curso/2011/pdf/PO1-G4.pdf.

Li, Yulin; Douglas Albert Johnson; Yongzhong Su; Jianyuan Cui & Tonghui Zhang. Specific leaf area and leaf dry matter contents of plants growing in sand dunes. Botanical Bulletin of Academia Sinica. 2005; 46:127-134.

Melo Júnior, João Carlos Ferreira de. Plasticidade morfológica e diversidade funcional de comunidades florísticas em gradiente edáfico na Restinga do Parque Estadual do Acaraí, São Francisco do Sul/SC [Tese de Doutorado]. Curitiba: Universidade Federal do Paraná; 2015.

Melo Júnior, João Carlos Ferreira de & Maria Regina Torres Boeger. Leaf traits and plastic potential of plant species in a light-edaphic gradient from a restinga in southern Brazil. Acta Biologica Colombiana. 2016; 21:51-62.

Melo Júnior, João Carlos Ferreira de & Maria Regina Torres Boeger. Riqueza, estrutura e interações edáficas em um gradiente de restinga do Parque Estadual do Acaraí, estado de Santa Catarina, Brasil. Hoehnea. 2015; 42:207-232.

Pereira, Oberdan José. Levantamento florístico e fitossociológico de uma área de restinga do estado do Espírito Santo [Dissertação de Mestrado]. Rio de Janeiro: Universidade Federal do Rio de Janeiro; 1990.

Poorter, Hendrik. Construction costs and payback time of biomass: a whole plant perspective. In: Roy, Jacques & Éric Garnier (eds.). A whole-plant perspective on carbon-nitrogen interactions. The Hague: SPB Publishing; 1994. p. 111-127.

Reich, Peter B.; David S. Ellsworth; Michael B. Walters; James M. Vose; Charles Gresham; John C. Voun & Willian D. Bowman. Generality of leaf trait relationships: a test across six biomes. Ecology. 1999; 80:1955-1969.

Ronquim, Carlos Cesar. Conceitos de fertilidade do solo e manejo adequado para as regiões tropicais. Campinas: Embrapa Monitoramento por Satélite; 2010.

Santos, Gabriel de Araújo & Flávio Anastácio de Oliveira Camargo. Fundamentos da matéria orgânica: ecossistemas tropicais e subtropicais. Porto Alegre: Genesis; 1999.

Scarano, Fábio Rubio. Structure, function and floristic relantioships of plants communities in stressful habitats marginal to Brazilian Atlantic Rainforest. Annals of Botany. 2001; 90:517-524.

Schlichting, Carl D. The evolution of phenotypic plasticity in plants. Annual Review of Ecology & Systematics. 1986; 17:667-693.

Shipley, Bill & Thi-Tam Vu. Dry matter content as a measure of dry matter concentration in plants and their parts. New Phytologist. 2002; 153:359-364.

Silva, Karolline Raimundo da & João Carlos Ferreira de Melo Júnior. Variações fenotípicas em *Andira fraxinifolia* Benth. (Fabaceae) em duas fitofisionomias de restinga. Hoehnea. 2016; 43(2):229-237.

Souza, Vinicius Castro & Lindolpho Capellari Júnior. A vegetação de dunas e restingas da Estação Ecologia da Juréia-Itatins. In: Marques, Otávio & Wânia Duleba (Orgs.). Estação Ecológica Juréia-Itatins – ambiente físico, flora e fauna. Ribeirão Preto: Holos; 2004. p. 103-114.

STCP Engenharia de Projetos Ltda. Projeto de proteção da mata atlântica em Santa Catarina. Estudo antropológico do Parque Estadual Acaraí. Curitiba; 2009.

Sultan, Sonia E. Phenotypic plasticity for plant development, function and life history. Trends in Plant Science. 2000; 5:537-542.

Ulian, Carina; Hebert Kondrat; Tauana Cunha & Thayná Mello. Assimetria de folhas de *Dalbergia ecasophyllum* (Fabaceae) expostas a estresses ambientais múltiplos na faixa costeira. Acervo Biblioteca Universidade de São Paulo, São Paulo; 2012.

Valladares, Fernando; David Sanchez-Gomez & Miguel Angel de Zavala. Quantitative estimation of phenotypic plasticity: bridging the gap between the evolutionary concept and its ecological applications. Journal of Ecology. 2006; 94:1103-1116.

Valladares, Fernando; Sagrario Arrieta; Ismael Aranda; David Lorenzo; David Tena; David Sanchez-Gomez; Francisco Suarez & José Alberto Pardos. Shade tolerance, photoinhnibition sensitivity and phenotypic plasticity of *Ilex aquifolium*. Tree Physiology. 2005; 25:1041-1052.

Valladares, Fernando; John B. Skillman & Robert W. Pearcy. Convergence in light capture efficiencies among tropical forest understory plants with contrasting crown architectures: a case of morphological compensation. American Journal of Botany. 2002; 89:1275-1284.

Vasconcelos, Márcio dos Santos; Maria Auxiliadora Milaneze-Gutierre & Paulo Inada. Utilização de verniz vitral como meio de montagem de laminários permanentes de material vegetal. Arquivos do Mudi. 2006; 10:32-35.

Witkowski, Edward T. F. & Byron B. Lamont. Leaf specific mass confounds leaf density and thickness. Oecologia. 1991; 88:486-493.

Zech, Wolfgang; Nicola Senesi; Georg Guggenberger; Klaus Kaiser; Johannes Lehmann; Teodoro Miano; Anja Miltner & Götz Schroth. Factors controlling humification and mineralization of soil organic matter in the tropics. Geoderma. 1997; 79:117-161.

Zimmermann, Martin Huldrych. Xylem structure and the ascent of sap. Berlin: Springer-Verlag; 1983. 160 p.